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PHYSICS OF NANOSTRUCTURES

Formation Mechanism of Argon Clathrates with Carbon Dendrites

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Abstract—The formation mechanism of argon clathrates with carbon dendrites obtained in the plasma of an atmospheric-pressure gas discharge has been studied. It has been shown that the formation of these clathrates is due to the difference between characteristic times: the lifetime of molecules surrounding argon atoms and the time of C–C bonding. It has been noted that argon clathrates with carbon dendrites can form only if a number of conditions are met: formation of molecular traps in the discharge, provision of a sufficiently low temperature at the center of the arc discharge, and the presence of active carbon particles arising from plasma decomposition of hydrocarbon precursors. Whether or not these conditions are met depends primarily on the composition of the initial hydrocarbon mixture and discharge current density, as follows from experimental data.

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It is known that atoms of inert gases (Ar, Kr, Xe) may be confined in the crystal lattice of a substance the molecules of which form hydrogen bonds. Such compounds are called clathrates [1, 2]. However, a number of works [3, 4] have appeared recently where inert gas atoms were discovered in submicrometer particles of solids with an amorphous structure. Such objects are very promising for medical applications. For example, clathrates that include radioactive isotopes of inert gases and carbon or silicon submicrometer particles may be applied in radionuclide therapy of oncological diseases [5, 6]. In this field of application, precision control of radiation (hence, precision control of the number of inert gas isotopes in submicrometer particles) is required. In turn, to provide precision control of the number of inert gas isotopes in fabricating their clathrates with submicrometer particles, it is necessary to have a clear sense of their formation mechanism, which is not always obvious. After argon clathrates with carbon dendrites obtained in the arc discharge plasma were discovered, an excimer mechanism of their formation was hypothesized [3]. The aim of this work was to gain a deeper insight into the formation mechanism of inert gas clathrates with carbon dendrites.

The typical structure of a carbon dendrite obtained in the arc discharge plasma [3] is presented in Fig. 1.

In general, three regions can be distinguished in the cross section of a carbon dendrite obtaining an arc discharge (Fig. 1): (*1*) core, (*2*) intermediate layer, and (*3*) outer sheath. In each region, the dendrite structure differs in accordance with growth conditions, hydrocarbon precursors from which the dendrite forms, dis-

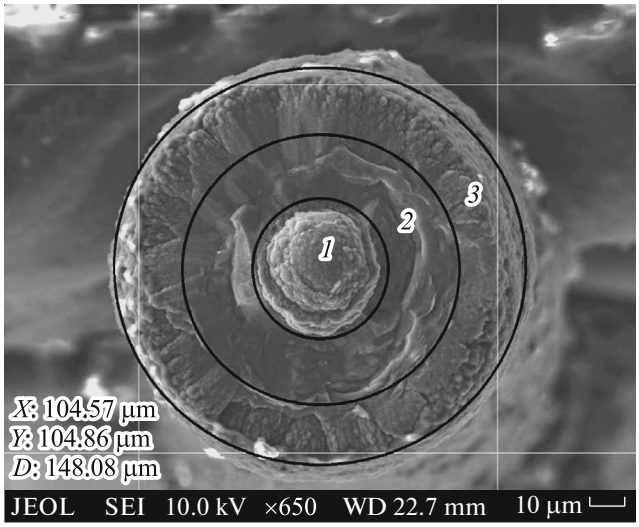

Fig. 1. Typical cross-sectional view of the carbon dendrite.